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THE FOSSIL MOLLUSCA OF THE PEPPERMINT GROVE LIMESTONE, SWAN RIVER DISTRICT OF WESTERN AUSTRALIA

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INTRODUCTION

Late-Pleistocene marine fossils are exposed along the banks of the lower Swan River at intervals below Freshwater Bay. They are found at heights up to 30 feet above sea level, and have been observed by the author nowhere more than $2\frac{1}{2}$ miles from the sea (see map).

Attention to the fauna has been sporadic over the years. J. L. Reath (1925) listed species found, and suggested that, as many did not appear to be living south of Geraldton, the deposit indicated warmer sea temperatures than at present. It was however recognised that "future work may weaken the case for a recent cooling of ocean temperatures."

The value of Reath's paper is vitiated by uncertain identifications, limited knowledge of living distributions, and obsolete nomenclature. Also the work does not differentiate between the fauna of the Peppermint Grove Limestone, and that of the younger unconsolidated shell beds which are so conspicuous in and near the Swan River below Rivervale.

Fairbridge (1953) described the formation and named it, as above, after one prominent exposure. He associated it with the 25 ft. rise in sea-level which occurred during the first warm interval of the Würm glaciation. No faunal re-examination was conducted, and general endorsement was expressed of Reath's tentative conclusion regarding the "warmer water character" of the deposit.

Carrigy and Carrigy (1952) discussed the fauna of a Mid-Recent beach deposit at Mosman Park. They questioned the correctness of some aspects of Reath's conclusions, and reported that the Mosman Park deposit "gave no evidence of a change in temperature during the time of the 10 foot sea level."

The significance of such fossil deposits, composed almost entirely of living species, can best be seen in direct comparison with the living fauna of the region, with this latter providing the measuring stick. At the outset of this work, it became clear that not enough was known of the distribution and composition of Western Australian mollusca to allow a proper comparison to be made.

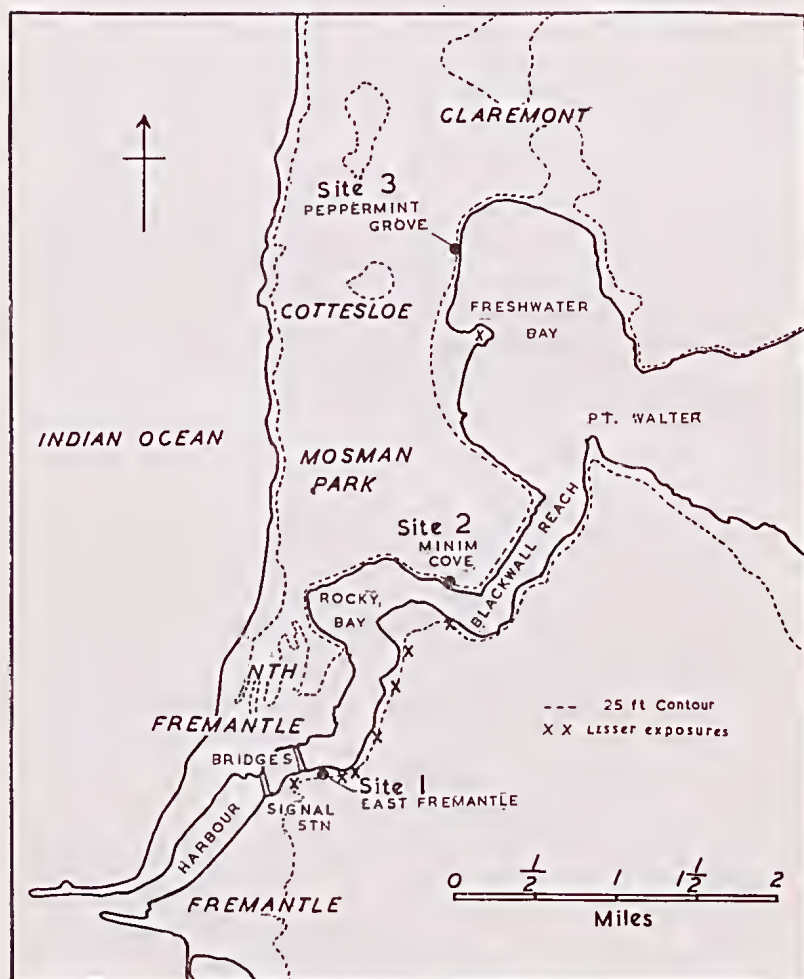
This deficiency has to some extent been remedied during several years' collecting by members of the Marine Research Group of the

W.A. Naturalists' Club, with which the author is associated. Localities which have provided living material include: Hopetoun, Bremer Bay, Cheyne Beach, Albany, Point D'Entrecasteaux, the Cape Naturaliste area, the coast from Shoalwater Bay to Cottesloe, Garden and Rottnest Islands, the waters of Cockburn Sound, Yanchep, the Geraldton district, some Abrolhos Islands, Shark Bay and Port Samson. It is the author's desire that the new information in this work will add to our understanding of Late-Pleistocene conditions in South-Western Australia.

METHODS OF EXAMINING THE FOSSIL MATERIAL

Specimens were obtained from three sites, one of which, at East Fremantle, has not been reported on prior to this work.

1. **East Fremantle:** Situated on the south bank of the Swan River; 150 yards upstream from the Fremantle Traffic Bridge; at



Locality map of exposures of fossils.

the foot of the Canning Highway embankment, 15 yards from the water's edge and 10 feet above low water. A pocket of shell two feet thick is mixed with rounded travertine pebbles and occasional rolled corals in a coarse brown shell-sand. Solution pipes pierce the shell layer, which overlies a soft rock containing scattered shells. Specimens were taken with ease from the exposed face to a depth of 12 inches and a note made of their relative abundance.

Small exposures of shells may be seen several hundred yards west of this site, and at intervals upstream to Blackwall Reach.

2. Minim Cove: Situated on the north bank of the Swan River between Rocky Bay and Blackwall Reach. The deposit may be seen over several hundred yards of the cliff-edge. Two samples were taken.

Lower sample: The largest sample worked. Several lbs. of the less-consolidated shell sand from 7 feet above low water were finely sieved. The residue, chiefly mollusc remains, was carefully sorted and counted. Each gastropod shell with apex intact was counted as one individual; every two pelecypod valves with hinges intact were counted as one individual. In addition, several species were identified from fragments showing characteristic detail. A small number of pelecypod chips with hinges were too worn or damaged to be identified or compared with other material, and have been omitted from the analysis.

Upper sample: From the highest coherent level of shell-sand, immediately above the lower sample, and about 20 feet above low water. Sorting and counting proceeded as above.

3. Peppermint Grove: Situated on the north bank of the Swan River, near the Scotch College boatshed, Freshwater Bay. Several lbs. of coarse shell sand were taken from the upper level of a conspicuous shell band 20 feet above low water. One sample only was worked; sorting and counting as previously described.

METHODS OF COLLECTING LIVING MOLLUSCA

The localities have already been referred to. In addition to scouring reefs and beaches, the aqualung, diving mask and schnorkel have been used to obtain alive the more elusive forms. Dredging has been successful in Cockburn Sound. Beach rolled shells in good condition have been accepted as an indication of living occurrence in a proportion of cases. All significant material so collected is in the collection of the W.A. Naturalists' Club, at the W.A. Museum, Perth.

Information so obtained which relates to species occurring in the fossil beds is included in the following tables.

RESULTS

These are essentially a comparison of living and fossil occurrences. Living distributions may be viewed broadly in three groupings, each of a particular significance to the fossil assemblages. The following key to categories is proposed.

Group A, comprising all fossil species which are also found living within 35 miles of Fremantle. Species are of several zoogeographical affinities, as follows:

A₁—species considered to be of north-west and/or Indo-Pacific affinity (Dampierian Province).

A₂—species considered to be of southern affinity (Flindersian and Peronian Provinces).

A₃—others, including species of uncertain affinity.

Group B, comprising all fossil species known to occur in life in Indo-Pacific waters (Dampierian Province), but *not collected alive south of Geraldton*.

Group C, comprising all fossil species known to occur in life along the south and south-east coasts of Australia (Flindersian-Peronian Provinces), but *not collected alive north of Cape Leeuwin*.

TABLE 1.—EAST FREMANTLE

84 species were observed, of which 70 were identified sufficiently for comparison with living material.

The 10 most conspicuous are:

Species	Living occurrence	Key (as above)
1. <i>Senectus pulcher</i> Reeve.	Northern Aust.-Geraldton-C.	Naturaliste-Hopetoun
2. <i>Katelsia rhytiphora</i> Lamy.	Albany-Victoria-Tasmania	
3. <i>Patellanax laticostata</i> (Blainville).	Geraldton-Recherche	
4. <i>Eumarcia fumigata</i> (Sowerby).	South Aust.-Tas.-Vic.-N.S.W.	
5. <i>Hormomya</i> ? sp. nov., identical with a species of uncertain identity collected living between the Abrolhos and Cockburn Sound		
6. <i>Fragum erugatum</i> (Tate).	Shark Bay-Geraldton-Rottneest and Sth. Aust. (rare). A single specimen also from Port Samson	
7. <i>Redicirce plebeia</i> (Hanley).	North-west Australia-Cockburn Sound	
8. <i>Haliotis roei</i> Gray.	Geraldton-Sth. Aust.	
9. <i>Dicathais aegrota</i> (Reeve).	Geraldton-Recherche	
10. <i>Antisabia erma</i> Cotton.	Cape Naturaliste-Geraldton	

Other species noted are:—

11. <i>Glycymeris striatularis</i> (Lamarek).	Geraldton-S.A.-sthn. N.S.W.	
12. <i>Anadara trapezia</i> (Deshayes).	Victoria-sthn. Qld., also Albany, W.A.	
13. <i>Gabinaarca symetrica</i> (Reeve).	N.W. Australia-Geraldton-Cockburn Sound	
14. <i>Barbatia pistachya</i> (Lamarek).	Geraldton-Vic.-N.S.W.	
15. <i>B. laminata</i> Angas.	Geraldton-Sth. Aust.	
16. <i>Ostrea angasi</i> Sowerby.	Cockburn Sound-Sth. Aust.-N.S.W.	
17. <i>Crassostrea</i> cf. <i>tuberculata</i> (Lamarek).	Cockburn Sound	
18. <i>Spondylus tenellus</i> Reeve.	Cockburn Sound-Sth. Aust.-N.S.W.	
19. <i>Mytilus planulatus</i> Lamarek.	Cockburn Sound-Victoria	
20. <i>Septifer bilocularis</i> Linne.	North-west Aust.-Cape Naturaliste	
21. <i>Eucrassatella verconis</i> Iredale.	Cockburn Sound-Sth. Australia	
22. <i>Wallucina assimilis</i> (Angas).	Geraldton-Victoria	
23. <i>Codakia bella</i> Conrad.	Cockburn Sound-Geraldton-northern Australia	
24. <i>Divalucina occidua</i> Cotton and Godfrey.	Safety Bay-South Australia	
25. <i>Fulvia tenuicostata</i> (Lamarek).	Cockburn Sound-Vic.-N.S.W.	
26. <i>Regozara flava</i> (Linne).	N.W. Aust.-Geraldton-Cockburn Sound-Israelite Bay	
27. <i>Katelsia scalarina</i> (Lamarek).	Albany-Victoria	
28. <i>Gomphina undulosa</i> (Lamarek).	Geraldton-Victoria	
29. <i>Venerupis</i> cf. <i>iris</i> (Linne).	Cockburn Sound-Yanchep-Geraldton	
30. <i>Narano lucinalis</i> (Lamarek).	Yanchep-Victoria	
31. <i>Homalina deltoidalis</i> (Lamarek).	Cockburn Sound-Victoria	
32. <i>Macoma dispar</i> Conrad.	Northern Australia	
33. <i>Angulus perna</i> Spengler.	Northern Australia-Cockburn Sound	
34. <i>Flavomala biradlata</i> (Wood).	Cockburn Sound-Victoria	
35. <i>Donax columbella</i> Lamarek.	Geraldton-Albany	
36. <i>Deltachion brazieri</i> (Smith).	Geraldton-Sth. Aust.	

37.	<i>D. chapmani</i> (Gatliff and Gabriel), Geraldton-Victoria	A ₂
38.	<i>Maetra pura</i> Deshayes, Geraldton-Victoria	A ₂
39.	<i>Mesodesma nitida</i> Deshayes, Sthn. Australia	C
40.	<i>Amblychilepas nigrita</i> (Sowerby), Geraldton-Victoria-sthn. Qld.	A ₂
41.	<i>Clanculus consorbrinus</i> Tate, Geraldton-Sth. Australia	A ₂
42.	<i>Herpetopoma aspersa</i> (Philippi), Geraldton-Tasmania	A ₂
43.	<i>Clanculus personatus</i> (Philippi), Cockburn Sound	A ₃
44.	<i>Austrocochlea rudis</i> (Gray), Geraldton-Recherche	A ₂
45.	<i>Caatharidus pulcherrimus</i> (Wood), Geraldton-Victoria	A ₂
46.	<i>Euninella gruneri</i> (Philippi), Geraldton-Tasmania	A ₂
47.	<i>Ninella whitleyi</i> Iredale, Geraldton-sthn. Australia	A ₂
48.	<i>Muaditia australis</i> (Klener), Fremantle-Victoria	A ₂
49.	<i>Notoacmea onychitis</i> (Menke), Yanchep-Albany	A ₂
50.	<i>Patelloida alticostata</i> (Angas), Geraldton-sthn. Aust.-sthn. Qld.	A ₂
51.	<i>P. nigrosulcata</i> (Reeve), Geraldton-Victoria	A ₂
52.	<i>Patellanax peroai</i> (Blainville), Fremantle-Victoria	A ₂
53.	<i>Melapaphe unifasciata</i> (Gray), Shark Bay-sthn. Aust.-sthn. Qld.	A ₂
54.	<i>Tectarius rugosus</i> Menke, Pt. Peron-north-west Australia	A ₁ *
55.	<i>Notosetia nitens</i> (Frauenfeld), Shark Bay-stha. Aust.-Victoria	A ₂
56.	<i>Sabia coalca</i> Schumacher, Geraldton-Tasmania	A ₂
57.	<i>Antisabia</i> sp. Fremantle and Geraldton	A ₃
58.	<i>Cacozellana granarium</i> (Klener), Geraldton-Sth. Australia	A ₂
59.	<i>C. icarus</i> (Boyle), Cockburn Sound	A ₃
60.	<i>Eubittium lawleyanum</i> (Crosse), Albany-Victoria	C
61.	<i>Vertagus asper</i> (Lamarck), North-west Aust.-Cape Naturaliste	A ₁
62.	<i>Granuliscala granosa</i> (Quoy & Gaimard), Cockburn Sound-Victoria	A ₂
63.	<i>Notocochlis marochiensis</i> (Gmelin), Fremantle-Albany	A ₂
64.	<i>Polinices conicus</i> (Lamarck), Shark Bay-Albany-Victoria-sthn. Qld.	A ₂
65.	<i>Bedevea paivae</i> (Crosse), Cockburn Sound-Victoria	A ₂
66.	<i>Euplia bidentata</i> Menke, N.W. Australia-Pallinup R. (east of Albany)	A ₁
67.	<i>Fusus australis</i> (Quoy & Gaimard), Fremantle-Victoria	A ₂
68.	<i>Oliva australis</i> Duclos, Geraldton-Victoria	A ₂
69.	<i>O. orata</i> Marrat, North-west Australia-Geraldton	B
70.	<i>Dyraspis dorreeasis</i> (Peroa), Shark Bay-Pallinup River (east of Albany)	A ₃

Thus, of the above 70 species, 62 live today in the vicinity of Fremantle (Group A). Of these, 44 show affinity with the fauna of southern Australia (A₂); ten with that of north-west Australia (A₁), and eight are of uncertain affinity (A₃). Six species are not now found living north of Cape Leeuwin (Group C). Only two species appear today to be restricted to warmer waters north of Geraldton (Group B).

ECOLOGY

Animals from the following three habitats are present in this assemblage: 1. Open rocky shore or reef flat, characterised by *Haliotis*, *Patellanax*, *Senectus*, *Dicathais*, etc. 2. Sandy beach with moderate exposure, characterised by *Gomphina*, *Glycymcris*, *Deltachion*, *Maetra*, etc. 3. Sheltered shallow marine gulf, a sandy to muddy bed, probably with sea grass, characterised by *Redicirce*, *Katelsysia*, *Eumarcia*, *Anadara*, *Polinices*.

An examination of the species and their habitats reveals the following fact. Those from the first two—open reef and open beach—correspond closely with present day living species along the lower west coast. However, species from the sheltered gulf habitat include almost all of those which have not been collected alive in this region. These are *Katelsysia* spp., *Eumarcia* (both conspicuous and

* See note at foot of p. 61.

dominant elements), *Anadara*, *Mesodesma* and *Eubittium*. Their present living occurrences on the south and south-east coasts of the continent, do not indicate warmer sea temperatures at the time of deposition.

The two species of Group B—*Macoma dispar* and *Oliva ornata*—are of slight occurrence and are considered of little significance in the balance of affinity.

TABLE 2.—MINIM COVE—LOWER SAMPLE

58 species were observed, of which 32 were identified sufficiently for comparison with living material. Of the recognised species, 13 contributed 1% or over of all individuals, and these are as follows:—

Species	Number present	Approx. per cent	Living occurrence	Key (as above)
1. <i>Notosetia nitens</i> (Frauenfeld)	1861	31	Shark Bay-sthn. Aust.-Vle.	A ₂ *
2. <i>Fragum erugatum</i> (Tate)	964	18	Shark Bay - Geraldton-Rott-nest-Sth. Aust. (rare)	A ₂
3. <i>Katelsia rhytiphora</i> Lamy	495	9	Albany-Victoria-Tasmania	C
4. <i>Diala lauta</i> A. Adams	437	8	Cockburn Snd.-Tas.-Vle.	A ₂
5. <i>Eumarcia funigata</i> (Sowerby)	416	8	Sth. Aust.-Tas.-Vle.-N.S.W.	C
6. <i>Diala lirulata</i> Thiele	269	5	Shark Bay	B
7. <i>Katelsia scalarina</i> (Lamarek)	127	2	Albany-Victoria	C
8. <i>Wallucina assimilis</i> (Angas)	123	2	Geraldton-Victoria	A ₂
9. <i>Haminoea brevis</i> (Quoy & Gaimard)	114	2	Cockburn Snd.-Vle.-Tas.	A ₂
10. <i>Diala translucida</i> Hedley	112	2	Cockburn Snd.-Vle.-Tas.	A ₂
11. <i>Electroma</i> cf. <i>georgiana</i> (Quoy & Gaimard)	110	2	Cockburn Sd.-C. Naturaliste	A ₂
12. <i>Elachorbis tatei</i> (Angas)	72	1	South Australia	C
13. <i>Redicirce plebeia</i> (Hanley)	55	1	N.W. Aust.-Cockburn Sound	A ₁
Other species (all under 1%), in order of frequency, are:—				
14. <i>Macoma dispar</i> Conrad	43		Northern Australia	B
15. <i>Retusa apicina</i> (Gould)	29		Cockburn Snd.-Vle.-Tasmania	A ₂
16. <i>Venerupis</i> cf. <i>iris</i> (Linne)	16		Cockburn Sound-Yanchep-Geraldton	A ₃
17. <i>Angulus perna</i> Spengler	7		N.W. Aust.-Cockburn Sound	A ₁
18. <i>Cacozeliana icarus</i> (Boyle)	6		Cockburn Sound	A ₃
19. <i>Zeacumantus cerithium</i> (Quoy & Gaimard)	5		Vle.-Sth. Aust.-Tasmania	C
20. <i>Cavatidens perplexa</i> Cotton and Godfrey	4		Geraldton-Victoria	A ₂
21. <i>Laternula creccina</i> (Reeve)	3		Cockburn Snd.-Vle.-N.S.W.	A ₂
22. <i>Bullaria botanica</i> Hedley	1		Geraldton-Victoria-N.S.W.	A ₂
23. <i>Anadara trapezia</i> (Deshayes)	1		Vle.-sth. Qld.-also Albany	C
24. <i>Notocochlis marochiensis</i> (Gmelin)	1		Cockburn Sound-Albany	A ₂
25. <i>Thracia alciope</i> Angas	1		North-west Australia	B
26. <i>Calliostoma interruptum</i> Wood	1		Geraldton-Albany	A ₂
27. <i>Akera soluta</i> (Gmelin)	1		Cockburn Sound-Victoria	A ₂
28. <i>Mesodesma nitida</i> Deshayes	1		South Australia	C
29. <i>Hormomya</i> ? sp. nov.	1		Cockburn Sound-Geraldton	A ₃
30. <i>Senectus pulcher</i> Reeve (operculum)	1		N. Aust.-Abrolhos-Hopetoun	A ₁
31. <i>Ethmonilia vitiliginea</i> Menke	1		Cockburn Sound-Albany	A ₂
32. <i>Spirula spirula</i> Linne	1		World-wide range	A ₃

26 indeterminate species totalling 226 specimens.

Grand total of 5,505 specimens of 58 species.

* See note at foot of p. 61.

The species identified sufficiently for comparison with living material total 32. These 32 species comprise 96% of all specimens, and are therefore an adequate basis for estimating the zoogeographical significance of the fauna.

Group A contains 22 species, and 3,849 specimens, aggregating 70% of all specimens.

A₁ contains 3 species and 63 specimens (1% of all specimens).

A₂ contains 14 species and 2,798 specimens (51% of all specimens).

A₃ contains 5 species and 988 specimens (18% of all specimens).

Group B contains 3 species, and 313 specimens (6% of all specimens).

Group C contains 7 species, and 1,117 specimens (20% of all specimens).

Thus, approximately 70% of all individual specimens in the sample are found living at present along the lower west coast of Western Australia, near Fremantle. A further 20% are found east, but not north, of Cape Leeuwin. Only 6% at present show exclusive affinity with the fauna of north-west Australia. Warmer sea temperatures are not indicated, in the author's view, by the composition of this fauna. Shallow marine-gulf conditions prevailed at the time of deposition. *Spirula* and *Senectus* suggest that the site was not completely free from contact with the open sea.

TABLE 3—MINIM COVE—UPPER SAMPLE

36 species were observed, of which 20 were identified sufficiently for comparison with living material. Of the 20 recognised species, 12 contributed 1% or over of all individuals, and these are as follows:—

Species	Number present	Approx. per cent	Living occurrence	Key (as above)
1. <i>Notosetia nitens</i> (Frauenfeld)	315	41	Shark Bay-sthn. Aust.-Vic.	A ₂ [*]
2. <i>Eumarcia fumigata</i> (Sowerby)	139	18	Sthn. Aust.-Tas.-Vic.-N.S.W.	C
3. <i>Diala lauta</i> A. Adams	96	13	Cockburn Snd.-Tas.-Victoria	A ₂
4. <i>D. lirulata</i> Thiele	31	4	Shark Bay	B
5. <i>Fragum erugatum</i> (Tate)	28	4	Shark Bay - Geraldton-Rott-nest-Sth. Aust. (rare)	A ₃
6. <i>Wallucina assimilis</i> (Angas)	21	3	Geraldton-Victoria	A ₂
7. <i>Diala translucida</i> Hedley	23	3	Cockburn Sound-Vic.-Tas.	A ₂
8. <i>Haminocia brevis</i> (Quoy & Gaimard)	19	2.5	Cockburn Sound-Vic.-Tas.	A ₂
9. <i>Redicirce plebeia</i> (Hanley)	12	2	Cockburn Snd.-N.W. Aust.	A ₁
10. <i>Retusa apicina</i> (Gould)	8	1	Cockburn Sound-Vic.-Tas.	A ₂
11. <i>Katelsysia scalarina</i> (Lamareck)	8	1	Albany-Victoria	C
12. <i>Zeacumantus cerithium</i> (Quoy & Gaimard)	8	1	Sth. Aust.-Vic.-Tas.	C
Other species (all under 1%), in order of frequency, are:—				
13. <i>Katelsysia rhytiphora</i> Lamy	3		Albany-Victoria-Tasmania	C
14. <i>Electroma</i> cf. <i>georgiana</i> (Quoy & Gaimard)	3		Cockburn Snd.-C. Naturaliste	A ₂
15. <i>Flavomala biradiata</i> (Wood)	2		Cockburn Snd.-Vic.-Tas.	A ₂
16. <i>Antisabia erma</i> Cotton	2		C. Naturaliste-Geraldton	A ₂
17. <i>Hormomya</i> ? sp. nov.	1		Cockburn Sound-Geraldton	A ₃

* See note at foot of p. 61.

18. <i>Homalina deltoidalis</i> (Lamarek)	1	Cockburn Sound-Victoria	A ₂
19. <i>Venerupis</i> cf. <i>iris</i> (Linne)	3	Cockburn Sound-Yanchep-Geraldton	A ₃
20. <i>Bullaria botanica</i> Hedley	1	Geraldton-Victoria-N.S.W.	A ₂
16 indeterminate specimens totalling 32 specimens.			
Grand total of 757 specimens of 36 species.			

The species identified sufficiently for comparison with living material total 20. These 20 species comprise approximately 95% of all specimens, and are therefore an adequate basis for estimating the zoogeographical significance of the fauna.

Group A contains 15 species, and 536 specimens (71% approx. of all specimens).

A₁ contains 1 species, and 12 specimens (2% of all specimens).

A₂ contains 11 species, and 494 specimens (65% of all specimens).

A₃ contains 3 species, and 30 specimens (4% of all specimens).

Group B contains 1 species and 31 specimens (4% of all specimens).

Group C contains 4 species and 158 specimens (20% of all specimens).

Approximately 70% of the fauna is known to be living today along the lower west coast (Group A). A further 20% of specimens is today found living east, but not north, of Cape Leeuwin (Group C). There is a small element (Group B) of from 4-6%, not known to live at present south of Geraldton.

The fossil fauna indicates the presence of a shallow marine gulf with a sandy to muddy bed. Present-day distributions of the component species do not support the estimate of warmer sea temperatures at the time of deposition.

Four species from the Minim Cove samples (*Homalina*, *Flavomala*, *Bullaria* and *Akera*) are living today in the Swan River estuary. However, all four also occur in marine conditions in Cockburn Sound.

The two levels sampled at Minim Cove are shown by this analysis to be of the same essential character and composition, and need not further be compared for the purposes of this work.

TABLE 4.—PEPPERMINT GROVE

One sample was examined. 36 species were observed, of which 22 were identified sufficiently for comparison with living material. Of the recognised species, 12 contributed 1% or over, of all individuals, and these are as follows:—

Species	Number present	Approx. per cent	Living occurrence	Key (as above)
1. <i>Diala lauta</i> A. Adams	243	30	Cockburn Sound-Tas.-Vic.	A ₂
2. <i>Elachorbis tatel</i> (Angas)	190	23	South Australia	C ₁
3. <i>Zeacumantus cerithium</i> (Quoy & Gaimard)	86	11	Victoria-Sth. Aust.-Tasmania	C
4. <i>Eumarcia fumigata</i> (Sowerby)	46	6	Sth. Aust.-Tas.-Vic.-N.S.W.	C
5. <i>Redicirce plebeia</i> (Hanley)	39	5	N.W. Aust.-Cockburn Snd.	A ₁

6. <i>Cacozeliana granarium</i> (Klener)	35	4	Geraldton-Sth. Australia	A ₂
7. <i>Wallucina assimilis</i> (Angas)	25	3	Geraldton-Victoria	A ₂
8. <i>Calliostoma interruptum</i> Wood	22	3	Geraldton-Albany	A ₂
9. <i>Notosetia nitens</i> (Frauenfeld)	20	2	Shark Bay-S. Aust.-Victoria	A ₂ *
10. <i>Diala lirulata</i> Thiele	20	2	Shark Bay	B
11. <i>D. translucida</i> Hedley	15	2	Cockburn Snd.-Victoria-Tas.	A ₂
12. <i>Parcanassa pauperata</i> (Lamarek)	15	2	Fremantle-Victoria-Tas.	A ₂

Other species (all under 1%), in order of frequency, are:—

13. <i>Cacozeliana icarus</i> (Boyle)	7	Cockburn Sound	A ₂
14. <i>Cavatidens perplexa</i> Cotton & Godfrey	4	Geraldton-Victoria	A ₂
15. <i>Flavomala biradiata</i> (Wood)	3	Cockburn Sound-Vic.-Tas.	A ₂
16. <i>Haninoea brevis</i> (Quoy & Gaimard)	3	Cockburn Sound-Vic.-Tas.	A ₂
17. <i>Katelsysia scalarina</i> (Lamarek)	2	Albany-Victoria	C
18. <i>Anadara trapezia</i> (Deshayes)	1	Vic.-sthn. Qld.-Albany, W.A.	C
19. <i>Hormomya</i> ? sp. nov.	1	Cockburn Sound-Geraldton	A ₂
20. <i>Antisabia erma</i> Cotton	1	Cape Naturaliste-Geraldton	A ₂
21. <i>Fragum erugatum</i> (Tate)	1	Shark Bay - Geraldton-Rott- nest-Sth. Aust. (rare)	A ₂
22. <i>Cadulus occiduus</i> Verco	1	Cockburn Sound	A ₂

14 indeterminate species, totalling 37 specimens.

Grand total of 817 specimens of 36 species.

There are 22 species identified sufficiently for comparison with living material. These amount to over 95% of all specimens, and are therefore an adequate basis for estimating the zoogeographical significance of the fauna.

Group A contains 16 species and 435 specimens (54% of all specimens).

A₁ contains 1 species and 39 specimens (5% of all specimens).

A₂ contains 11 species and 386 specimens (48% of all specimens).

A₃ contains 4 species and 10 specimens (1% of all specimens).

Group B contains 1 species and 20 specimens (2% of all specimens).

Group C contains 5 species and 325 specimens (39% of all specimens).

Approximately 54% of this fauna lives at the present day along the lower west coast of Western Australia adjacent to Fremantle. A further 39% is now found living east, but not north, of Cape Leeuwin. A mere 2% of specimens has not been collected living south of Geraldton.

Compared with the Minim Cove fauna, the Peppermint Grove assemblage suggests stronger affinities with the southern Australian region, and slightly weaker affinities with the north-west region.

Once again, shallow marine gulf conditions are indicated. The fauna does not suggest warmer sea temperatures at time of deposition.

* *Notosetia* has not actually been observed by the author living in the Fremantle region; its presence may be reasonably presumed from other definite records which are referred to.

DISCUSSION

1. Along the western coast of Western Australia between Shark Bay and Cape Leeuwin, the mollusca of the Dampierian (north-west) and Flindersian-Peronian (south-west to south-east) Provinces overlap and intermingle.

2. In addition there appears to be a small, though noticeable group of mollusc species of seeming "western" affinity which do not, on the basis of present knowledge, conform strictly to either of the other major groupings.

3. As could be expected, therefore, a similar mixed composition of the fossil assemblages has been observed—roughly comparable to the present living suites.

4. Ecological gradients between Shark Bay and Cape Leeuwin tend to be gradual and widely spaced. Thus the Late-Pleistocene fossil records from near Fremantle (160 miles from Cape Leeuwin, and 400 miles from Shark Bay) are particularly well placed to judge such changes in species distributions as have occurred.

5. *The Dampierian Element* in the fossil assemblages is referred to in the Key as "A₁" (those which extend southwards to at least as far as Cockburn Sound) and "B" (those not known to occur alive south of Geraldton). The Dampierian species are summarised as follows:—

Site	No. of spp. in Group A ₁	No. of spp. in Group B	Total spp. A ₁ + B	Total no. of identified spp.— all groups
East Fremantle	10	2	12	70
Minim Cove				
upper	1	1	2	20
lower	3	3	6	32
Peppermint Grove	1	1	2	22

Some prominent representatives of this element are: *Redicirce plebeia*, *Angulus perna*, *Macoma dispar*, *Diala lirulata*, *Septifer bilocularis*, *Gabinaurca symmetrica*, *Scnectus pulcher* and *Vertagus asper*.

6. *The Flindersian-Peronian Element* in the fossil assemblages is clearly the dominant one, and is referred to in the Key as "A₂" (those species living today near Fremantle) and as "C" (those not known to occur north of Cape Leeuwin. They are summarised as follows:—

Site	No. of spp. in Group A ₂	No. of spp. in Group C	Total spp. A ₂ + C	Total no. of identified spp.— all groups
East Fremantle	41	6	50	70
Minim Cove				
upper	11	4	15	20
lower	14	7	21	32
Peppermint Grove	11	5	16	22

Some prominent representatives of this element are: *Katclysia* spp.,† *Patellanax* spp., *Eumarcia fumigata*,† *Haliotis roei*, *Dicath-*

† These, with *Elachorbis tatei*, are not now found north of C. Leeuwin.

ais aegrota, *Barbatia pistachya*, *Wallucina assimilis*, *Flavomala biradiata*, *Deltaehion* spp., *Patelloida alticostata*, *Notosetia nitens*, *Polinices conicus*, *Diala lauta*, *D. translucida*, *Elaeorbis tatei* and *Haminoca brevis*.

Worthy of note is the wide distribution of some members of this group. For example, *Notosetia*—Shark Bay to Victoria; *Polinices*—southern Queensland via the southern coast to Shark Bay. B. Wilson has collected specimens from Port Samson which appear indistinguishable from this species.

7. Some miscellaneous species in the fossil assemblages of seeming western affinity are referred to in the Key as A₃. In some cases this is due to lack of sufficient knowledge of their full range. However, others may prove to be valid exceptions from either of the two major provincial affinities.

Fragum erugatum: A single record exists from Port Samson. The species is strongly developed, with much variation, at Hamelin Pool, Shark Bay (from where it has been known as *hamelini* Ireland). It occurs sparsely in south-western W.A. (Geraldton, Rottnest). It also occurs in South Australia where it is not common.

Venerupis cf. iris: This Linnean species was described from the Mediterranean. The W.A. shell, while approaching the other, is reported to be smaller. Very occasionally specimens have been collected from beaches of Cockburn Sound, Yanchep and the Geraldton district.

Dyraspis dorreensis: This has been collected living from numerous localities between Shark Bay and the Pallinup River, to the east of Albany.

Hormomya ? sp. nov. This is a species of common living occurrence between Cockburn Sound, Geraldton and the Abrolhos. The limits of its range are not yet known with certainty. The species is morphologically distinct from *Brachidontes rostratus* Dunker and *H. erosus* Lamarck. Hitherto it appears to have been referred to under the former of these names.

Of interest also is the wide range of the Dampierian species *Euplicia bidentata* and *Senectus puleher*, which have been collected living east of Cape Leeuwin as far as the Pallinup River and Hopton, respectively (advice from B. Wilson).

8. The living and fossil faunas may be directly compared as follows:

The reef and open beach forms in the East Fremantle deposit compare very closely with contemporary forms from such habitats.

The sheltered gulf forms from all three fossil deposits differ principally from the local Fremantle fauna in the presence of a conspicuous southern element, not now known to occur north of Cape Leeuwin. There is also a smaller group of Indo-Pacific forms, not known to occur south of Geraldton. Notwithstanding the above, the largest part of the fossil suite has direct affinity with waters adjacent to Fremantle at the present day.

9. Ecology. The fossil suites (East Fremantle partly excepted) are composed of species found living under sheltered marine condi-

tions mainly along the western, southern and south-eastern coasts of the continent. At present, however, there is no habitat in the region directly comparable with the Late-Pleistocene Perth Gulf presumed to have existed from this work. Consequently one cannot expect a close correlation between the fossil assemblages and the local living ones. For this reason it has been necessary to examine the faunas of sheltered water habitats both to the north and south of the Swan River.

It is significant that many elements of the fossil Gulf fauna are today found living in nearby Cockburn Sound.

Since the time of deposition, a succession of events has led to the virtual disappearance of the marine gulf and its specialised fauna. Eustatic fluctuation has at times converted the gulf to dry land and extended the coastline to the west of present-day Rottnest. Marine gulf conditions were finally re-established during the Recent eustatic "high," only to be abruptly terminated by the onset of heavy regular winter flooding in the Swan River system.

The present living distributions of the gulf species which have been listed would, if taken together, range over most, if not all, of the Australian coastline (wherever the habitat is suitable). From this alone, however, one would be reluctant to concede that they share the ability to constitute one community. Yet relatively recently this was the case. The presence of many of the fossil species in the Perth Gulf was apparently marginal in relation to their range, thus leading earlier workers to concentrate attention on possible water temperature changes in their environment.

Closer study of the biology and ecology of the species concerned would no doubt reveal the common tolerances and aptitudes which they possess.

10. The present living mollusca of the lower Swan River estuary (below Perth) have little in common with the fossil groupings. Some common species are:

<i>Monia ione</i> Gray	<i>Bembicium melanostoma</i>
<i>Mytilus planulatus</i> Lamarck	(Gmelin)
<i>Modiolus pulex</i> Lamarck	<i>Diala pulchra</i> A. Adams
<i>Kellia australis</i> Lamarck	<i>Bedevea paivae</i> (Crosse)
<i>Venerupis evenata</i> Lamarck	<i>Marinula patula</i> Lowe
<i>Homalina deltoidealis</i> (Lamarck)	<i>Bullaria botanica</i> Hedley
<i>Flavomala biradiata</i> (Wood)	<i>Akera soluta</i> (Gmelin)
<i>Hiatella australis</i> (Lamarck)	
<i>Velacumantus australis</i> (Quoy	
& Gaimard)	

Save *Velacumantus*, all the above have been observed locally in marine conditions. Heavy winter flooding now prevents the establishment of wholly marine forms in the Swan River estuary, as pointed out by Serventy (1955, p. 29), who has also drawn attention to the confusing citation by Hedley (1916) of the term "Swan River" as a locality reference. Hedley gives 123 species as occurring in the Swan River. Actually this refers to the Swan River Colony, as understood in the last century, and not to the Swan River proper.

INTERPRETATION

1. Shell deposits exposed in cliffs along the lower Swan River indicate the presence in Late-Pleistocene times of a marine gulf on the site of the present estuary. This occupied the low-lying area east of a sheltering peninsula now represented by the hills between North Fremantle and Claremont. The gulf opened to the sea through reefs and sandbanks between Fremantle and Leighton, the entrance being probably wider than the present estuary channel.

2. The sheltered and exposed shores of this peninsula each supported a characteristic mollusc fauna. Shells from three habitats (open reef, open beach, and sheltered gulf) were deposited after death by water movement to form the East Fremantle deposit. Reef and beach forms from this site closely correspond with present-day species in the region.

3. Within the gulf a specialised mollusc fauna was developed chiefly from the appropriate and more adaptable elements of both the southern and northern faunas. This fauna was essentially marine in character, not estuarine.

4. Since deposition the character of the gulf and its fauna have changed profoundly due to eustatic fluctuations and the advent of estuarine winter flooding. A proportion of the fauna, being some species of marginal occurrence, has not subsequently been able to maintain itself in the region. Most of such "absent" forms, being elements of the Flindersian-Peronian faunas, are now found in southern waters east of Cape Leeuwin. A lesser number, representative of the Dampierian fauna, are today living north of Geraldton. Further collecting may yet reveal the presence of some of these "absent" species (especially northern ones) still living in the vicinity of Fremantle.

Further information on the biology and ecology of the dominant forms is required.

5. The comparison which has been made of the fossil species and their present living distributions does not endorse previous estimates of a lowering of sea temperatures in south-western Australia since Late-Pleistocene times. Environmental changes are suggested as a significant factor in producing changes in mollusc distributions.

NOTES ON NOMENCLATURE

1. *Wallucina assimilis* (Angas, 1861) = *W. jacksoniensis* Smith, 1885. For discussion see Ludbrook, *Trans. Roy. Soc. S. Aust.*, 78, 1955: 51.

2. *Senectus pulcher* Reeve, 1843 = *Turbo intercostalis* Menke, 1846.

3. *Katechysia rhytiphora* Lamy, 1937 = *Venus strigosa* auct. and *Venus corrugata* auct., non Lamarek, 1818.

4. *Hormomya* ? sp. nov. Appears to have been considered previously as a western form of *Brachidontes rostratus* Dunker, 1856.

5. *Fragum erugatum* (Tate, 1888) = *Fragum hamelini* Iredale, 1949.

6. *Zeacumantus eerithium* (Quoy & Gaimard, 1834) = *Z. diemenensis*, 1834 of the same authors.

7. *Dyraspis dorreensis* (Peron, 1807) = *Conus pontificalis* Lamarck, 1810.

8. *Notocoehlis murehiensis* (Gmelin, 1801) = *N. gualteriana* Reeluz, 1844.

9. *Amblychilepas* takes precedence over the synonym *Sophismelepas*.

LOCATION OF SPECIMENS

All recent material referred to in this work has been placed in the mollusc collection of the W.A. Naturalists' Club, at the Western Australian Museum, Perth. Fossil material has been retained temporarily by the author but will be donated to the Museum after further identification has been completed.

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